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A Preliminary Investigation of the Effect of Humidity on the Ignition, Heat Release, and Smoke Density Tests for Typical Room Finishing Materials

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Interim Report

Prepared for
Naval Ships Systems Command
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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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by

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ABSTRACT

Nine commonly used room finishing materials were subjected to the heat release and ignition tests under development at NBS and to the NBS smoke density test. Each material was tested with three different moisture contents representing 50 percent relative humidity(RH), 0 percent RH, and one intermediate RH value. The purpose of the tests was to gain experience with the test methods under development in order to determine whether instrumental or procedural modifications are needed and (2) to examine the problem of testing a material at 50 percent RH and using it under much lower humidity conditions.

Some procedural changes are recommended for both the ease of ignition and the heat release rate tests. The rates of heat release were found to be as much as 50 percent higher for the dried specimens than for those conditioned at 50 percent RH. The ignition times were found to decrease by as much as 50 percent after being dried.

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Key Words: building materials, fire tests, heat release, ignition, smoke density

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A Preliminary Investigation of the Effect of Humidity on the Ignition, Heat Release, and Smoke Density Tests for Typical Room Finishing Materials

1.0 INTRODUCTION

The Building Fires and Safety Section of the Center for Building Technology at the National Bureau of Standards is active in the design of fire test methods for building materials. The radiant panel has been accepted as ASTM Standard Test E-162[1]*. A test for potential heat[2] and the smoke density chamber[3] are being considered for adoption as ASTM Standards. Tests for the ease of ignition[4] and the rate of heat release[5] are under development. Additional tests on ignition and flame spread are anticipated. The tests are normally performed at NBS on specimens which have equilibrated in a 68 °F atmosphere with a relative humidity of 50 percent. Materials which may indicate a low hazard under these conditions might prove to be a high hazard where the relative humidity in a typical room is much lower. In order to gain some experience with the ease of ignition and heat release rate tests on typical interior finishing materials and to determine the sensitivity of these tests to the relative humidity, the measurements described in this report were conducted. Tests for the sensitivity of optical density of the smoke to the relative humidity were also included.

Since a fairly large amount of materials were examined in a short time, the number of repetitions was necessarily small. Hence these measurements must be considered preliminary. Nevertheless, some conclusions on the effect of moisture can be drawn and enough information

* Superscripts refer to the references to the literature.

can be provided to form the basis of more comprehensive tests at a later date.

2.0 MATERIALS

The materials examined included solid red oak 25/32 in. thick with and without three coats of floor varnish; 1/2-in. regular gypsum board with one coat of fire retardant vinyl latex paint (Note: the undercoat recommended by the manufacturer was not used on these specimens), with two coats of flat latex paint, with a predecorated 10 mil vinyl coat, and with an uncoated surface; 4-mil prefinished Lauan mahogany plywood; 1/2-in. natural wood fiber insulating board; and 1/4-in. tempered hardboard. All of these materials were tested without any backing. The painting of the gypsum board and the varnishing of the oak were done in the laboratory.

3.0 MOISTURE CONTENT

In order to find the length of time which specimens must be kept in the conditioning room to achieve a constant weight at 50 percent relative humidity and to determine the time and temperature requirements to produce dry specimens, the following measurements were made on samples of oak.

The weight change as a function of conditioning time is illustrated in figure 1. In Run "A" the specimens were cut as received from boards obtained from a local lumber yard and put in a 60 °C oven. A constant weight loss of 16 percent was achieved after five days. The oven temperature was increased to 115 °C after seven days and another 4 percent

was lost within four days. Another group of specimens was conditioned to a constant weight loss in a room whose relative humidity was maintained at 50 percent and were then heated at 115°C in an oven for 24 hours with a weight loss of 7-1/2 percent. It took 17 days in the 50 percent RH conditioning room (Run "B") to bring their moisture content back up to a constant 4-1/2 percent. Part of the weight loss at 115°C was not recovered. In Run "C" the specimens from the 50 percent RH conditioning room were dried in a desiccator for 30 days before achieving a 6-1/2 percent weight loss. In Run "D" specimens from the same lot were dried in the oven at 60 °C for six days with a 6.7 percent weight loss.

From these preliminary measurements it appears that the specimens to be equilibrated at 50 percent RH should be in the conditioning room for at least 30 days and that dry specimens can be produced by heating materials either directly from the conditioning room or the lumber yard in a 60 °C oven for six days. The specimens heated in the oven at 115 °C appeared to have a greater weight loss than would be achieved by a building material exposed to low humidity atmospheres in practice and hence the faster drying time is not recommended. However, it is possible even with a low rate of evaporation that after many years of exposure in a low humidity atmosphere at ambient temperature, the greater weight loss could be achieved. For the purposes of these experiments, the specimens were assumed to be dry after heating at 60 °C for six days.

Each of the materials were tested under three moisture conditions: equilibrated at 50 percent relative humidity, dried in an oven at 60°C for 24 hours, and dried in an oven at 60 °C for six days. The middle

treatment was intended to produce an intermediate relative humidity condition. However, it does have the disadvantage of a non-uniform moisture distribution with the surface layers being drier than the interior.

For a more refined study, it is suggested that specimens representing intermediate relative humidity conditions be maintained in a constant humidity atmosphere until a constant weight loss is achieved. The conditioning times would vary with the materials and its thickness.

4.0 DESCRIPTIONS OF TESTS

4.1 Ease of Ignition

The ease of ignition test[4] utilized a pair of specimens 5-1/2 in. x 6 in. facing each other at a distance of 7/8 in. apart. They are exposed to a heat flux of 3 W/cm^2 produced by flame contact. The time to sustained ignition, i.e. the exposure time required to produce sustained flaming, is found by trial and error. The specimen is exposed for a predetermined period of time and the presence or absence of flaming is noted. The presence of flame at any point on the specimen one minute after exposure flame has been removed constitutes sustained ignition. The exposure time is then increased or decreased appropriately until the ignition time is bracketed. The ease of ignition test apparatus is represented schematically in figure 2.

4.2 Heat Release Rate

In the heat release rate calorimeter the front surface of a vertical specimen 4-1/2 in. x 6 in. which represents a small section of a wall is exposed to a thermal radiation level of 6 W/cm^2 from

three radiant panels similar to the one used in the radiant panel test[2]. The edges of the specimen are shielded and the rear surface is separated from a water cooled brass block by an air space. The brass block represents a small section of the wall behind the one represented by the specimen. The heat removed from the rear surface of the specimen is measured by the rate of temperature rise in the cooling water. A propane burner inside of the calorimeter produces heat at a considerably greater rate than that of the burning specimen. When the specimen is burning, the propane flow is automatically reduced by the amount necessary to maintain the flue gas temperature constant. The rate of heat release through the front surface of the specimen is determined from the reduction in propane flow. The heat released at the front surface only is quoted in this report. The calorimeter is represented schematically in figure 3.

4.3 Smoke Density

In the smoke density chamber[3] a specimen 3 in. x 3 in. is exposed to a thermal radiation level of 3 W/cm^2 from an electrical heating element. A small pilot flame may be employed to ignite the pyrolysis gases. However, the smoldering mode was used in the measurements reported here and the pilot was omitted. The smoke density chamber is 3 feet high, 3-feet wide, and 2-feet deep. The smoke density is measured over a vertical path from the floor to the ceiling with a S-4 response phototube and a tungsten light source.

5.0 TEST DATA

The data collected on the tests are included in Tables I through

IX. The data for each material are given in separate tables. The average moisture content is quoted along with the drying conditions at the left of the table. The exposure times which were used to determine the sustained ignition time are tabulated along with the number of sides of the specimen that ignited and the time of sustained flaming if it was less than 60 seconds. The estimated values of the times to ignition are stated. Each ignition time is based on six pairs of specimens. The calorimeter and smoke chamber data are based on three or four repetitions which are listed in the table followed by their average values. The exception is the total heat release which is based on only one measurement in order to avoid the long burning times.

The average values of the most important parameters are compared in Table X for each of the moisture conditions. Conditions 1, 2, and 3 are equilibration at 50 percent RH, held at 60°C for 24 hours and held at 60 °C for six days, respectively. The numbers in parentheses below the ignition times represent the percent moisture content for each material under conditions 1, 2, and 3. These moisture contents were assumed to be the same for the heat release and smoke specimens.

6.0 DISCUSSION OF RESULTS

6.1 Ease of Ignition

None of the coated gypsum board specimens sustained flaming in the ease of ignition test. The uncoated gypsum boards exhibited sustained flaming but only within a narrow range of exposure times. For longer times the fuel vapors would all be driven out during the exposure period. There appears to be a reduction in the ignition

time with increasing moisture content for the gypsum board. Even when flaming is sustained it is limited to small areas where the paper is in poor thermal contact with the substrate. Otherwise most of the heat required for pyrolysis is simply conducted into the comparably inert gypsum material and the flame cannot sustain itself without external sources of heat. The random nature of these areas of poor thermal contact can account for some of the scatter in the ignition data for gypsum board.

The ease of ignition test does not seem to provide any useful information regarding the fire hazard of gypsum board. While the test indicates that gypsum board ignites easier than red oak, the small flamelets were inconsequential compared with the much more intense flaming exhibited by the other materials when sustained flaming was established. The local flames on the gypsum board shortly extinguished themselves without involving a large percentage of the rest of the surface whereas the other materials after flaming for one minute burned to completion. As a result of these tests it seems desirable to add the additional restriction of a minimum area of flaming to the criteria for sustained flaming. For example, sustained flaming could be said to have occurred if there is a flaming area at least 2 inches wide at the end of 60 seconds. This width requirement is sufficient to exclude the small flamelets described above. Under these conditions only those specimens which burned to completion would have satisfied the criteria for sustained ignition.

All of the materials tested except for gypsum board showed a decrease in ignition time with decreasing moisture content. In some

cases these decreases were as much as 50 percent. This is due to the extra heat required to vaporize the water in moist specimens and to the greater flow of combustible vapors necessary to make up for the dilution by the water. There are other factors present in the case of the gypsum board that are apparently more important than the increase in heat content.

6.2 Heat Release Rate

The variation in the heat release rates with moisture content was within the rather large scatter of data except in the three following cases. The oak specimens with the three coats of varnish showed a substantial increase in the peak heat release rate with decreasing moisture content although there was no change in the highest one minute average heat release rate. The tempered hardboard and the Lauan paneling showed an increase in both the peak heat release rate and the highest one minute average heat release rate with decreasing moisture content. The observed increases in heat release rate with decreasing moisture content were as high at 50 percent. Both the tempered hardboard and Lauan paneling were thin enough to experience an appreciable temperature rise on the rear surface by the end of one minute.

The peak and the highest one minute average heat release rates were essentially the same, except for gypsum board and the varnished oak, indicating a nearly constant rate of heat release over the one minute duration. For those finished materials with a thin coating which is more combustible than the substrate, the time interval over which the averaging takes place has a strong influence on their ranking as to heat release rate. Although one minute has been

tentatively chosen as the averaging time in the heat release rate calorimeter based on the time required to ignite a typical building material by flame contact, the exact time is still rather arbitrary. The assignment of an arbitrary averaging time in which a slight change could qualify or disqualify a material would certainly be unacceptable from an industrial point of view. The heat release rate of all of the materials tested was nearly constant over a 15 second time interval. If the averaging time were reduced to 10 seconds the average heat release rate would be approximately equal to the peak heat release rate and independent of small changes in the averaging interval.

The specification of a finite averaging interval would still serve the purpose of eliminating the false identification of electrical or mechanical transients in the measuring system as the peak heat release rate. The peak and the highest 10 second average heat release rates are indistinguishable for the materials tested on this project. The peak heat release rate for the dried plain gypsum board was very close to that of the solid oak.

This would indicate a similar effect with regard to the heat release rate. However, the total heat release from the oak was over 30 times as high as that from the gypsum board. For building code purposes both the peak heat release rate and the total heat release should be quoted for a particular material. The limits should be established for each of these heat release parameters. For eventual use in the engineering design of buildings for fire safety, the complete curve of heat release rate versus time will be required.

Because of the limited amount of data obtained the expected trend

between the total heat release and the moisture content was not apparent. While the total heat released should be independent of the moisture content, the division of heat between the front and rear surfaces of the specimen could be altered. The total heat release quoted in the tables of this report refer only to that portion which is released at the front surface. Also the vaporization of the water consumes some heat that must be subtracted from the total.

6.3 Smoke Generation

There appears to be a significant increase in the smoke production with an increase in moisture content in the oak specimens, both varnished and unfinished. No trends are noted in the smoke production for the other materials tested relative to moisture content.

6.4 General

There is a scatter of up to 50 percent in the heat release data for a particular material at the same moisture content partly due to the performance of the measurement system and partly due to the variability of the materials including coating thicknesses. An extensive evaluation of the precision and accuracy of the heat release rate calorimeter is planned.

In Table XI the materials are ranked in descending order of their fire hazard in regard to ignition, peak heat release rate, total heat release and smoke density. The data for 50 percent RH was used for this ranking. The large difference in order illustrates the problem of designing a single fire test which will rank the materials in a unique order of fire hazard. The ranking orders would also depend to some extent on the relative humidity.

7.0 CONCLUSIONS

(1) Drying the specimens at 60 °C to a constant weight in the oven results in the same weight loss as drying them to constant weight in a desiccator at room temperature. This takes about six days for a 25/32-in. thick oak board at 60°C.

(2) The criteria for sustained ignition in the ease of ignition test should include a flaming area with a minimum width of two inches as well as a minimum flaming time of one minute. This would allow the presence of small flames which are too small to spread to other areas or to ignite other combustibles.

(3) With this additional requirement gypsum board coated and uncoated will not sustain ignition in the ease of ignition test.

(4) All of the other materials sustained ignition by the above definition and showed an increase in ignition time with moisture content.

(5) There was a significant increase in the heat release rate due to drying for some of the materials. For others the effect was within the present limits of error of the calorimeter.

(6) The ease of ignition and heat release rate tests should be run on materials conditioned to the lowest relative humidity that they would be likely to encounter in practice. (To be more exact, they should have the lowest moisture content encountered in practice which would depend on both the relative humidity and the ambient temperature.)

(7) In addition to supplying a curve of heat release rate versus time for analytical purposes, the results of the heat release

rate test should be characterized by two numbers for potential use in the building codes. These would be the peak heat release rate and the total heat released. In order to eliminate confusion with the electrical and mechanical transients in the measurement system, the peak value should be defined as the highest 10 second average. The actual peak and the highest 10 second average are indistinguishable for all of the materials tested in this project.

(8) Limits should be established for both the peak heat release rate and the total heat release.

(9) The differences in the relative ranking of the materials with regard to fire hazard by the ignition, heat release rate, total heat release, and smoke tests indicate the impossibility of designing a single test on which to classify the fire hazards of materials.

(10) The large scatter in the data included in this report indicates the need for improvements in the precision of the test methods.

8.0 RECOMMENDATIONS FOR FUTURE WORK

This preliminary set of tests should be repeated on an equivalent set of specimens chosen to include as large a variety of popular finishing materials as possible. Flame spread with the radiant panel, potential heat, and smoking in the flaming mode should be included among the tests as well as projected tests on critical incident heat flux for spontaneous ignition and critical incident heat flux for flame spread. The heat flux passing through the rear of the specimen as well as the heat leaving through the exposed surface should be

measured. The causes of the significantly large scatter in the data should be tracked down to either material variability or poor instrument precision or a combination of both.

Examine some small scale enclosure fires with these finishing materials as an exercise in determining how to evaluate the results of the tests in terms of a real enclosure fire. Use these materials to refinish a room in each of several houses which are scheduled to be burned down by the fire department. Compare the predictions obtained by use of the fire test results with temperature, heat flux, and smoke measurements in the full scale fire.

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APPENDIX

Conversion Factors for Units Used in the Text

1 Btu/(ft^2.sec) = 1.14 W/cm^2

1 inch = 2.54 cm

1 mil = 2.54 x 10^{-3} cm

1 foot = 0.305 m

140 °F = 60 °C

239 °F = 115 °C

Table I Data on Gypsum Wallboard 1/2 Inch Thick

Treatment	Ease of Ignition (3 Watts/cm²)			Heat Release Rate Calorimeter (6 Watts/cm²)				Smoke Density (Smoldering) (3 Watts/cm²)	
	Exposure Time (Sec.)	Sides Ignited	Sustained Flaming (Sec.)	Peak Heat Release Rate (Watts/cm²)	Highest One Minute Average Rate (Watts/cm²)	Time to Ignition (Sec.)	Total Heat Release (Joules/cm²)	Specific Optical Density (Ds)	Time to Peak (Sec.)
50% R. H.	96	0	0	8.58	8.08	26.9	352	64	540
AVERAGE	100	0	0	8.87	5.72	29.4		64	540
8.1% MOISTURE	106	1	>60	8.75	4.57	27.0		68	480
CONTENT	112	1	>60						
	115	1	>60						
	120	0	0						
	Time to Ignition = 103 Sec.			8.7*	6.1*	27.7*	352*	65*	520*
1 DAY AT 60	72	0	0	17.9	5.72	18.4	330	71	528
AVERAGE	84	0	0	20.2	6.86	19.8		73	540
7.1% MOISTURE	88	0	0	15.3	5.72	21.2		72	516
CONTENT	115	0	0	17.18	5.29	23.2			
	120	1	>60						
	132	0	0						
	Time to Ignition = 118 Sec.			17.6*	5.9*	20.6*	330*	72*	528*
6 DAYS AT 60°C	115	1	3	17.89	5.72	23.1		68	420
AVERAGE	120	1	6	15.02	4.43	23.5	339	74	456
0% MOISTURE	125	2	3	17.89	5.72	23.5		72	438
CONTENT	135	1	6						
	137	1	>60						
	139	1	>60						
	Time to Ignition = 136 Sec.			16.9*	5.3*	23.4*	339*	71*	438*

* Average Value

Table II Data on Gypsum Wallboard 1/2 Inch Thick (W/One Coat Vinyl Latex Fire Retardant Paint)

Treatment	Ease of Ignition (3 Watts/cm²)			Heat Release Rate Calorimeter (6 Watts/cm²)				Smoke Density (Smoldering) (3 Watts/cm²)	
	Exposure Time (Sec.)	Sides Ignited	Sustained Flaming (Sec.)	Peak Heat Release Rate (Watts/cm²)	Highest One Minute Average Rate (Watts/cm²)	Time to Ignition (Sec.)	Total Heat Release (Joules/cm²)	Specific Optical Density (Ds)	Time to Peak (Sec.)
50% R. H. AVERAGE 4.4% MOISTURE CONTENT	130	0	0	10.72	5.72	9.7		94	330
	140	0	0	12.16	5.57	10.5	463	104	342
	147	0	0	10.72	6.86	11.5		95	300
	155	0	0						
	165	0	0						
	180	0	0						
	Time to Ignition = ∞			11.2*	6.1*	10.6*	463*	97*	324*
1 DAY AT 60°C AVERAGE 3.7% MOISTURE CONTENT	90	0	0	10.15	6.86	17.3		97	360
	95	0	0	8.58	6.86	11.8		98	330
	105	0	0	10.72	5.57	20.0	339	104	372
	120	0	0						
	130	0	0						
	140	0	0						
	Time to Ignition = ∞			9.8*	6.4*	16.4*	339*	99*	354*
6 DAYS AT 60°C	90	0	0	10.72	6.86	12.6	532	95	270
	95	0	0	9.30	4.79	9.9		88	240
	105	0	0	10.01	1.57	11.6		88	240
	110	0	0						
	115	0	0						
	120	0	0						
	Time to Ignition = ∞			10.0*	5.4*	11.4*	532*	90*	250*

* Average Value

Table III Data on Gypsum Wallboard 1/2 Inch Thick (W/2 Coats Flat Latex Paint)

Treatment	Ease of Ignition (3 Watts/cm²)			Heat Release Rate Calorimeter (6 Watts/cm²)				Smoke Density (Smoldering) (3 Watts/cm²)	
	Exposure Time (Sec.)	Sides Ignited	Sustained Flaming (Sec.)	Peak Heat Release Rate (Watts/cm²)	Highest One Minute Average Rate (Watts/cm²)	Time to Ignition (Sec.)	Total Heat Release (Joules/cm²)	Specific Optical Density (Ds)	Time to Peak (Sec.)
50% R. H. AVERAGE 7.1% MOISTURE CONTENT	100	0	0	22.0	5.72	31.4		59	570
	110	2	14	18.86	5.14	23.0		56	540
	115	1	10	25.36	4.57	29.5	352	57	510
	120	1	30	15.0	3.50	21.0			
	132	0	0						
	145	0	0						
	Time to Ignition = ∞			20.3*	4.7*	26.2*	352*	57*	540*
1 DAY AT 60°C AVERAGE 6.3% MOISTURE CONTENT	100	0	0	25.36	5.14	27.3	330	62	510
	110	0	0	20.0	4.57	21.9		60	480
	115	1	20	20.35	5.07	21.9		59	480
	120	0	0	26.23	5.72	24.8			
	125	1	10						
	130	0	0						
	Time to Ignition = ∞			23.0*	5.1*	24.0*	330*	60*	490*
6 DAYS AT 60°C AVERAGE 0% MOISTURE CONTENT	95	0	0	15.0	4.57	16.4	248.8	52	414
	97	1	9	26.1	4.14	20.6	205.9	55	480
	100	0	6	26.4	3.43	21.0	235.9	57	492
	105	1	13	20.0	3.93	28.2	205.9		
	108	0	0	15.0	3.43	20.8			
	110	0	0						
	Time to Ignition = ∞			20.5	3.9*	21.4	224.1	54*	462*

* Average Value

Table IV Data on Gypsum Wallboard 1/2 Inch Thick (Covered W/010 Inch Vinyl)

Treatment	Ease of Ignition (3 Watts/cm²)			Heat Release Rate Calorimeter (6 Watts/cm²)				Smoke Density (Smoldering) (3 Watts/cm²)	
	Exposure Time (Sec.)	Sides Ignited	Sustained Flaming (Sec.)	Peak Heat Release Rate (Watts/cm²)	Highest One Minute Average Rate (Watts/cm²)	Time to Ignition (Sec.)	Total Heat Release (Joules/cm²)	Specific Optical Density (Ds)	Time to Peak (Sec.)
50% R. H. AVERAGE 7.1% MOISTURE CONTENT	95	0	0	6.73	4.57	15.0	626	122	486
	105	0	0	8.86	5.72	16.1		122	540
	115	0	0	10.01	3.64	15.0		127	510
	125	0	0	10.01	6.77	16.5			
	137	0	0						
	150	0	0						
	Time to Ignition = ∞			8.9	5.2	15.6	626*	123*	512
1 DAY AT 60°C AVERAGE 5.8% MOISTURE CONTENT	95	0	0	9.3	6.86	17.0		127	660
	105	0	0	8.58	5.72	15.5	532	117	720
	110	0	0	7.15	4.71	17.0		121	708
	117	0	0						
	130	0	0						
	143	0	0						
	Time to Ignition = ∞			8.3	5.8*	16.5*	532*	121*	696*
6 DAYS AT 60°C AVERAGE 0% MOISTURE CONTENT	65	0	0	8.15	6.86	8.0		112	456
	75	0	0	8.87	5.43	13.5	433.3	120	486
	85	0	0	11.4	10.29	13.0		105	522
	95	0	0						
	115	0	0						
	120	0	0						
	Time to Ignition = ∞			9.5*	7.5*	11.5*	433*	112*	488*

* Average Value

Table V Data on Lauan Mahogany Paneling 3/16 Inch Thick (Prefinished W/4 Mil)

Treatment	Ease of Ignition (3 Watts/cm²)			Heat Release Rate Calorimeter (6 Watts/cm²)				Smoke Density (Smoldering) (3 Watts/cm²)	
	Exposure Time (Sec.)	Sides Ignited	Sustained Flaming (Sec.)	Peak Heat Release Rate (Watts/cm²)	Highest One Minute Average Rate (Watts/cm²)	Time to Ignition (Sec.)	Total Heat Release** (Joules/cm²)	Specific Optical Density (Ds)	Time to Peak (Sec.)
50% R. H. AVERAGE 6.3% MOISTURE CONTENT	79	0	0	13.58	13.58	11.2		413	380
	84	0	0	12.0	12.0	8.2		438	378
	87	1	>60	12.88	12.88	9.2		369	372
	98	2	>60	12.88	12.88	11.4			
	108	2	>60						
	120	2	>60						
	Time to Ignition = 86 Sec.			12.8*	12.8*	10.0*		406*	370*
1 DAY AT 60°C AVERAGE 0.2% MOISTURE CONTENT	50	0	0	16.46	16.46	5.8		355	366
	55	1	3	17.75	17.75	6.0		390	354
	60	1	3	20.02	20.02	6.1		380	348
	66	0	0						
	69	0	0						
	72	1	>60						
	Time to Ignition = 70 Sec.			18.1*	18.1*	5.9*		375*	356*
6 DAYS AT 60°C AVERAGE 0% MOISTURE CONTENT	58	0	0	16.43	16.43	9.2		366	330
	60	0	0	17.18	17.18	8.4		396	300
	63	0	0	25.05	25.05	11.2		380	306
	66	2	>60						
	68	2	>60						
	73	2	>60						
	Time to Ignition = 65 Sec.			19.0*	19.0*	9.1*		380*	312*

* Average Value

** Specimens fell out of holder

Table VI Data on Tempered Hardboard 1/4 Inch Thick

Treatment	Ease of Ignition (3 Watts/cm²)			Heat Release Rate Calorimeter (6 Watts/cm²)				Smoke Density (Smoldering) (3 Watts/cm²)	
	Exposure Time (Sec.)	Sides Ignited	Sustained Flaming (Sec.)	Peak Heat Release Rate (Watts/cm²)	Highest One Minute Average Rate (Watts/cm²)	Time to Ignition (Sec.)	Total Heat Release** (Joules/cm²)	Specific Optical Density (Ds)	Time to Peak (Sec.)
50% R. H.	205	0	0	20.3	15.02	33.		920	660
AVERAGE	235	1	3	22.9	14.3	33.		922	660
4.1% MOISTURE	240	1	4	20.0	20.0	21.2		898	660
CONTENT	245	1	10						
	245	1	>60						
	250	1	>60						
	Time to Ignition = 245 Sec.			21.1*	16.4*	29.1*		913*	660*
1 DAY AT 60°C	160	1	10	25.38	25.38	15.5		915	600
AVERAGE	162	1	10	24.14	24.14	14.		919	600
0.3% MOISTURE	163	2	>60	23.92	23.92	16.		922	570
CONTENT	165	2	>60	23.30	23.30	16.			
	168	2	>60						
	176	2	>60						
	Time to Ignition = 163 Sec.			24.2*	24.2*	15.4*		918*	590*
6 DAYS AT 60°C	144	1	10	24.28	24.28	23.0			720
AVERAGE	150	1	9	25.05	25.05	21.2			498
0% MOISTURE	158	2	12	24.28	24.28	22.0		921	540
CONTENT	161	1	>60						
	163	2	>60						
	165	2	>60						
	Time to Ignition = 160 Sec.			24.5*	24.5*	22.1*		921*	586*

* Average Value

** Specimens fell out of holder

Table VII Data on Painted Wood Fiber Insulating Board

Treatment	Ease of Ignition (3 Watts/cm²)			Heat Release Rate Calorimeter (6 Watts/cm²)				Smoke Density (Smoldering) (3 Watts/cm²)	
	Exposure Time (Sec.)	Sides Ignited	Sustained Flaming (Sec.)	Peak Heat Release Rate (Watts/cm²)	Highest One Minute Average Rate (Watts/cm²)	Time to Ignition (Sec.)	Total Heat Release (Joules/cm²)	Specific Optical Density (Ds)	Time to Peak (Sec.)
50% R. H.	52	0	0	10.1	10.1	5.6	2880	300	960
AVERAGE	56	0	0	11.1	11.1	5.5		376	846
6.8% MOISTURE	60	0	0	10.7	10.7	6.1		421	822
CONTENT	68	1	4						
	71	1	3						
	75	1	>60						
	Time to Ignition = 73 Sec.			10.6*	10.6*	5.7*	2880*	365*	876*
1 DAY AT 60°C	36	1	12	12.15	12.15	10.2	3980	327	774
AVERAGE	38	2	>60	13.59	13.59	4.0		294	840
0.5% MOISTURE	40	2	>60	12.89	12.89	3.8		320	756
CONTENT	45	2	>60						
	49	2	>60						
	54	2	>60						
	Time to Ignition = 37 Sec.			12.9*	12.9*	6.0*	3980*	313*	790*
6 DAYS AT 60°C	30	0	0	10.01	10.01	7.5		343	834
AVERAGE	32	0	0	9.30	9.30	6.0		361	816
0% MOISTURE	34	2	>60	9.30	9.30	4.5	3290	371	828
CONTENT	36	2	>60						
	41	2	>60						
	45	2	>60						
	Time to Ignition = 33 Sec.			9.5*	9.5*	6.0*	3290*	358*	826*

* Average Value

Table VIII Data on Solid Red Oak 25/32 Inch Thick (Unfinished)

Treatment	Ease of Ignition (3 Watts/cm²)			Heat Release Rate Calorimeter (6 Watts/cm²)				Smoke Density (Smoldering) (3 Watts/cm²)	
	Exposure Time (Sec.)	Sides Ignited	Sustained Flaming (Sec.)	Peak Heat Release Rate (Watts/cm²)	Highest One Minute Average Rate (Watts/cm²)	Time to Ignition (Sec.)	Total Heat Release (Joules/cm²)	Specific Optical Density (Ds)	Time to Peak (Sec.)
50% R. H.	162	0	0	17.9	17.9	15.	11250	762	>1200
AVERAGE	162	1	3	18.6	18.6	15.1		759	>1200
6.7% MOISTURE	164	2	3	17.18	17.18	16.		731	>1200
CONTENT	166	1	>60						
	170	2	>60						
	180	2	>60						
	Time to Ignition = 165 Sec.			17.9*	17.9*	15.4*	11250*	751*	>1200*
1 DAY AT 60°C	125	0	0	19.48	19.48	9.		881	>1200
AVERAGE	128	1	3	20.02	20.02	10.2	11670	921	>1200
2.9% MOISTURE	130	1	3	19.61	19.61	8.		921	>1200
CONTENT	131	1	>60						
	141	1	>60						
	155	1	>60						
	Time to Ignition = 131 Sec.			19.7*	19.7*	9.*	11670	907*	>1200*
6 DAYS AT 60°C	100	0	0	17.9	17.9	15.5		959	>1200
AVERAGE	103	0	0	18.59	18.59	14.6	10900	960	>1200
0% MOISTURE	105	1	8	17.18	17.18	12.1		921	>1200
CONTENT	106	1	>60						
	108	1	>60						
	110	2	>60						
	Time to Ignition = 106 Sec.			17.9*	17.9*	14.1*	10900*	946*	>1200

* Average Value

Table IX Data on Solid Red Oak 25/32 Inch Thick (W/3 Coats of Clear Varnish)

Treatment	Ease of Ignition (3 Watts/cm²)			Heat Release Rate Calorimeter (6 Watts/cm²)				Smoke Density (Smoldering) (3 Watts/cm²)	
	Exposure Time (Sec.)	Sides Ignited	Sustained Flaming (Sec.)	Peak Heat Release Rate (Watts/cm²)	Highest One Minute Average Rate (Watts/cm²)	Time to Ignition (Sec.)	Total Heat Release (Joules/cm²)	Specific Optical Density (Ds)	Time to Peak (Sec.)
50% R. H.	120	0	0	61.5	19.32	29.5	12800	767	>1200
AVERAGE	125	0	0	34.5	19.32	21.3		761	>1200
6.1% MOISTURE	131	0	0	32.9	20.02	17.6		693	>1200
CONTENT	133	1	>60						
	137	1	>60						
	145	2	>60						
	Time to Ignition = 132 Sec.			42.9*	19.6*	22.8	12800*	740*	>1200*
1 DAY AT 60°C	90	0	0	43.7	20.02	18.	12400	920	>1200
AVERAGE	94	0	0	55.7	20.02	20.1		859	>1200
2.2% MOISTURE	96	0	0	56.2	21.2	25.		883	>1200
CONTENT	98	0	0						
	99	2	>60						
	110	2	>60						
	Time to Ignition = 99 Sec.			51.8*	20.4*	21.0*	12400*	887*	>1200*
6 DAYS AT 60°C	76	0	0	64.4	17.89	22.5		921	>1200
AVERAGE	78	0	0	65.5	17.89	29.1	14500	922	>1200
0% MOISTURE	80	0	0	61.5	18.18	27.7			
CONTENT	82	0	0						
	83	2	>60						
	88	2	>60						
	Time to Ignition = 83 Sec.			63.8*	18.0*	26.5*	14500*	921*	>1200*

* Average Value

Table X Summary of Test Results

Material	Time to Ignition			Peak Heat Release Rate			1 Min Avg Heat Release Rate			Total Heat Release			Smoke Density		
	C-1	C-2	C-3	C-1	C-2	C-3	C-1	C-2	C-3	C-1	C-2	C-3	C-1	C-2	C-3
Gypsum Board	103 (8.1)	118 (3.7)	136 (0)	8.7	17.6	16.9	6.1	5.9	5.3	206	343	339	65	72	71
Gypsum Board Fire Retardant Latex	∞ (4.4)	∞ (3.7)	∞ (0)	11.2	9.8	10.0	6.1	6.4	5.4	463	339	532	97	99	90
Gypsum Board Plus 2 Coats of Latex	∞ (7.1)	∞ (6.3)	∞ (0)	20.3	23.0	20.5	4.7	5.1	3.9	352	330	224	57	60	54
Gypsum Board Plus Predecorated Vinyl	∞ (7.1)	∞ (5.8)	∞ (0)	8.9	8.3	9.5	5.2	5.8	7.5	626	532	433	123	121	112
Lauan Panel	86 (6.3)	70 (.2)	65 (0)	12.8	18.1	19.0	12.8	18.1	19.0	Fell out of holder			406	375	380
Tempered Hardboard	245 (4.1)	163 (0.3)	160 (0)	21.1	24.2	24.5	16.4	24.2	24.5	Fell out of holder			913	918	921
Wood Fiber Insulating Board	73 (6.8)	37 (0.5)	33 (0)	10.6	12.9	9.5	10.6	12.9	9.5	2880	3980	3290	365	313	358
Red Oak	165 (6.7)	131 (2.9)	106 (0)	17.9	19.7	17.9	17.9	19.7	17.9	11250	11670	10910	751	907	946
Red Oak and 3 Coats of Varnish	132 (6.1)	99 (2.2)	83 (0)	43	52	64	19.6	20.4	18.0	12770	12420	14490	740	887	921

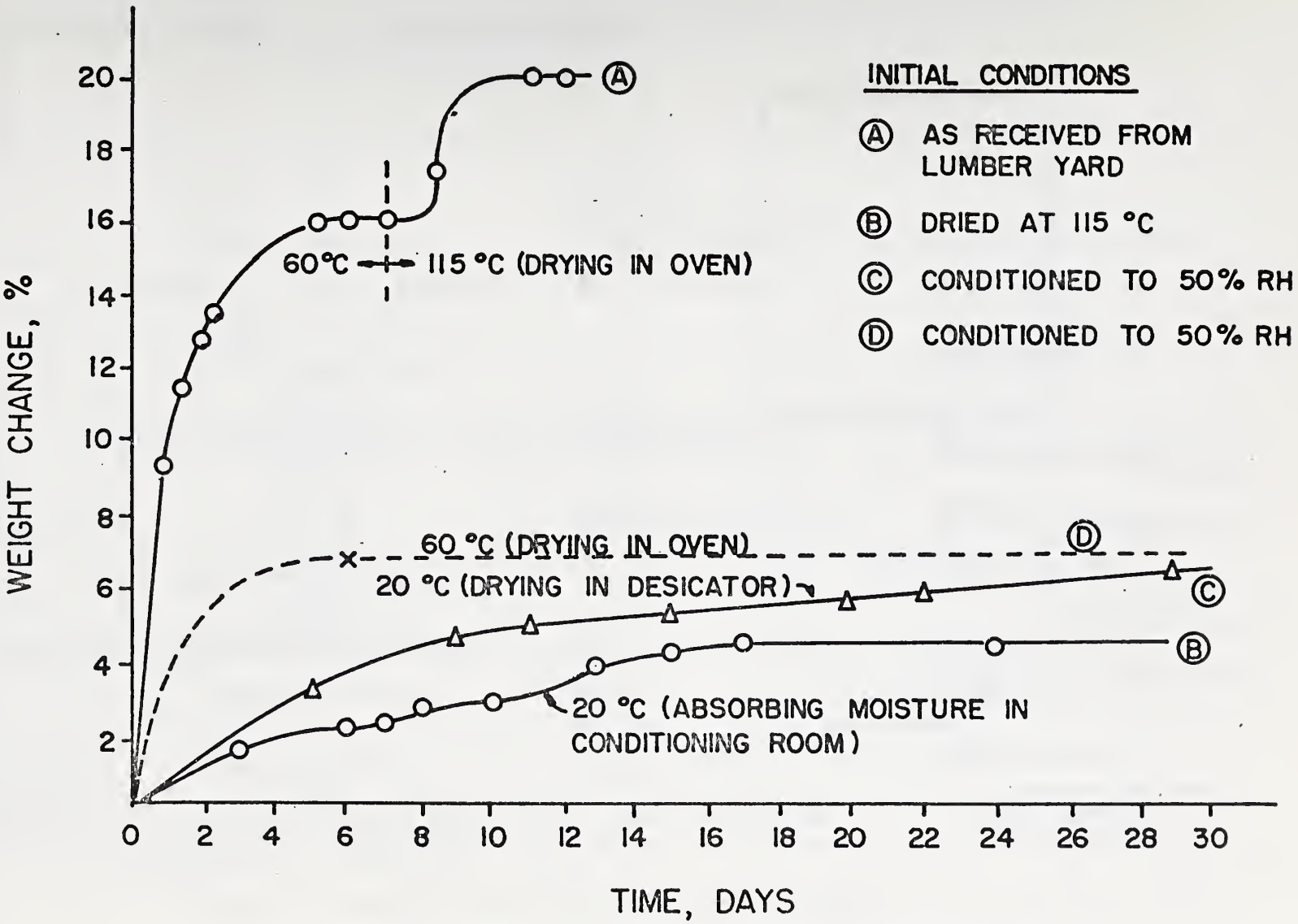

Figure 1. Weight Changes in Oak Specimens as a Function of Temperature and Time

Table XI Materials Listed in Order of Decreasing Hazard

Ignition	Heat Release Rate	Total Heat Released	Smoke Density
Wood Fiber Insulating Board	Red Oak & Varnish	Red Oak & Varnish	Tempered Hardboard
Lauan	Tempered Hardboard	Red Oak	Red Oak
Red Oak & Varnish	Gypsum Board & 2 Latex	Wood Fiber Insulating Board	Red Oak & Varnish
Red Oak	Red Oak	*	Lauan
Tempered Hardboard	Lauan	Gypsum Board with Vinyl Coating	Wood Fiber Insulating Board
Gypsum Board	Gypsum Board & Fire Retardant Latex	Gypsum Board & Fire Retardant Latex Coating	Gypsum Board & Vinyl Coat
	Wood Fiber Insulating Board	Gypsum Board & 2 Latex	Gypsum Board & Fire Retardant Latex
	Gypsum Board & Vinyl	Gypsum Board Plain	Gypsum Board Plain
	Gypsum Board Plain	*Tempered Hardboard & Lauan Samples fell out of holder. No data obtained.	Gypsum Board & 2 Latex

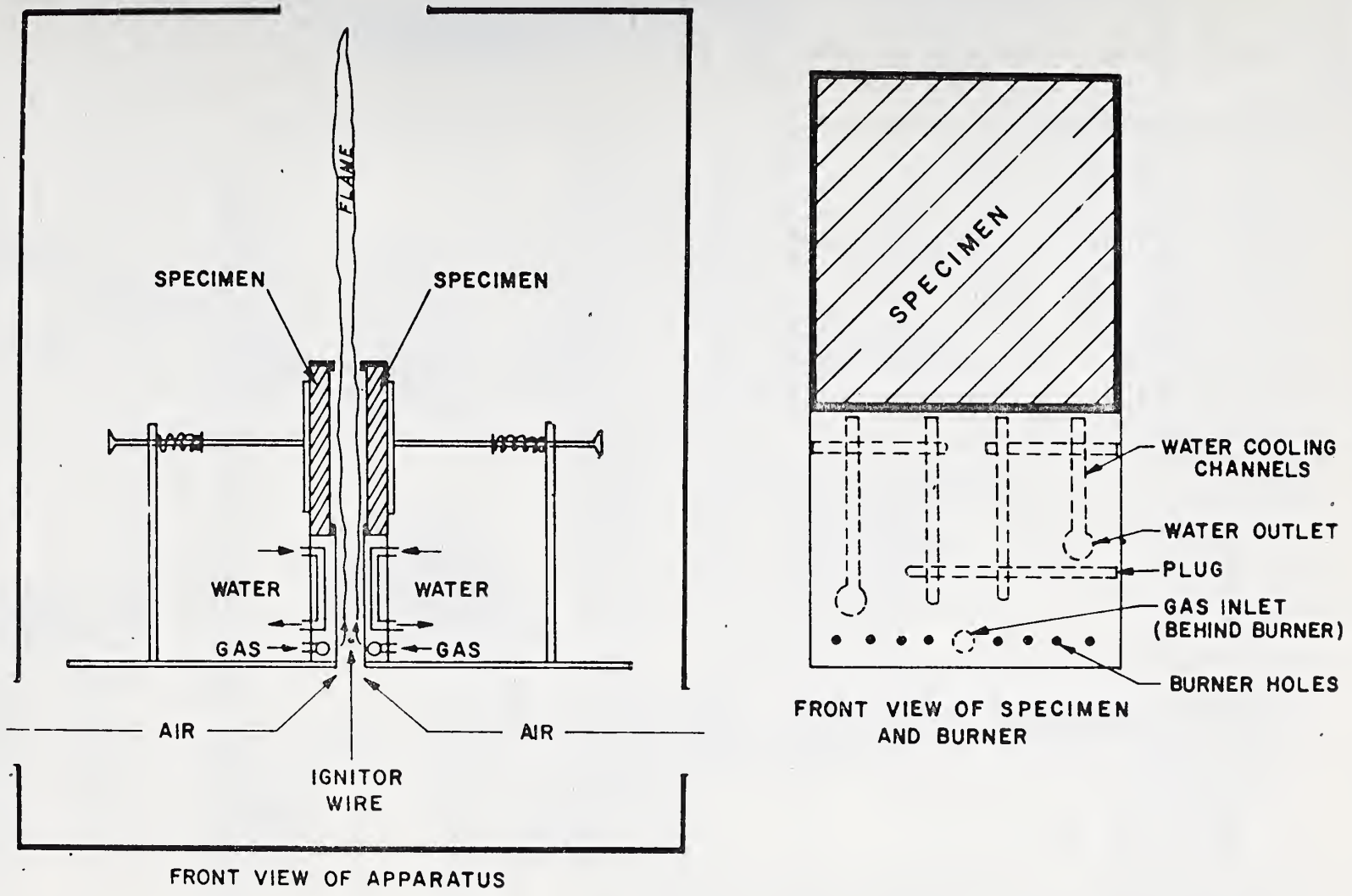

Figure 2. Ease of Ignition Apparatus

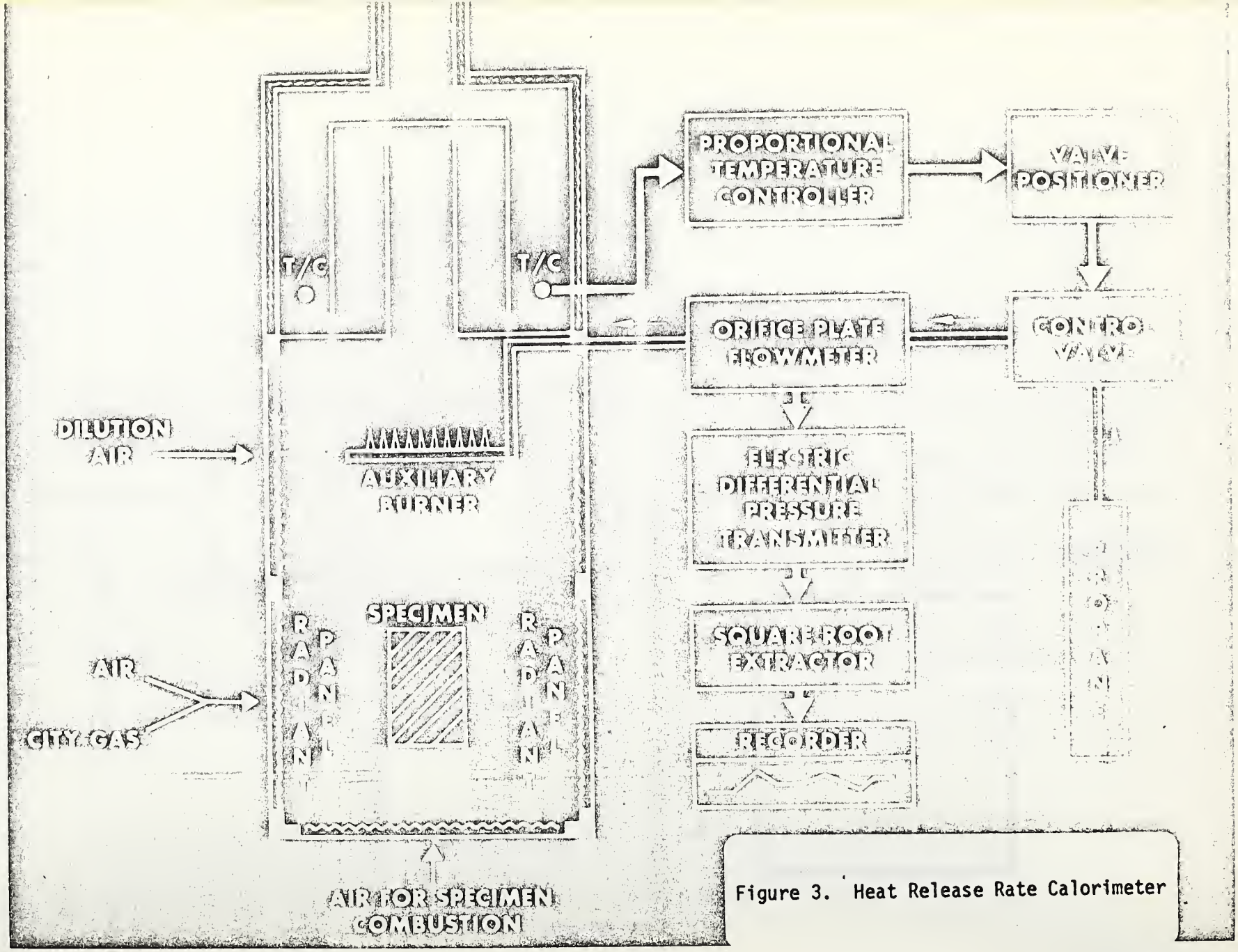

Figure 3. Heat Release Rate Calorimeter

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16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

Nine commonly used room finishing materials were subjected to the heat release and ignition tests under development at NBS and to the NBS smoke density test. Each material was tested with three different moisture contents representing 50% relative humidity (RH), 0% RH, and one intermediate RH value. The purpose of the tests was to (1) gain experience with the test methods under development in order to determine whether instrumental or procedural modifications are needed and (2) to examine the problem of testing a material at 50% RH and using it under much lower humidity conditions.

Some procedural changes are recommended for both the ease of ignition and the heat release rate tests. The rates of heat release were found to be as much as 50% higher for the dried specimens than for those conditioned at 50% RH. The ignition times were found to decrease by as much as 50% after being dried.

17. KEY WORDS (Alphabetical order, separated by semicolons)

Building materials; fire tests; heat release; ignition; smoke density

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